BELLCOMM, INC.

SUBJECT: MSC Spacecraft Pressure Vessel Testing Policy - Case 330

DATE: August 18, 1967

FROM: D. M. Duty

ABSTRACT

Results from fracture mechanics analysis of Apollo Block I titanium alloy pressure vessels are the basis of a proposed MSC spacecraft pressure vessel testing policy. The implementation of these results into uniform testing policies and operating criteria is discussed.

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MEMORANDUM FOR FILE

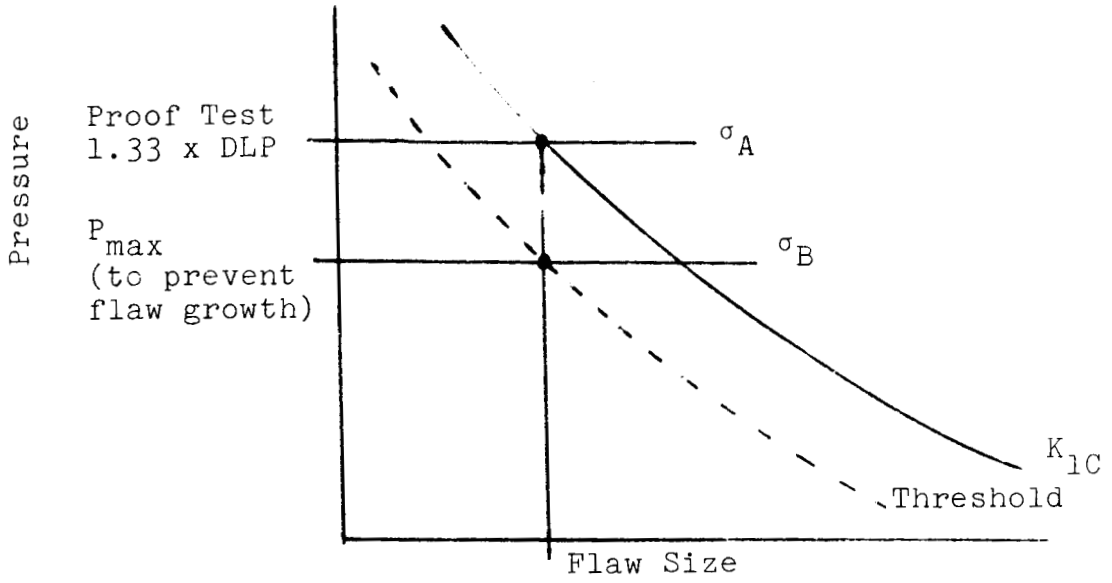
1.0 INTRODUCTION

A meeting was held at MSC August 15, 1967, to review pressure vessel operating criteria for the LM/CSM and to establish a uniform policy on testing of pressure vessels at the contractors' facilities and other locations. The meeting was chaired by Mr. L. M. Jenkins, PD 5, Systems Engineering, with representatives of NAA, GAEC, MSC and MAS/OMSF in attendance.

Fracture mechanics analysis of the Apollo titanium alloy pressure vessels was the basis of much of the discussions and preliminary policy decisions. Apollo Program Directive No. 23 is justification for implementing the results of the analysis into a testing policy which will provide guidelines for all testing operations.

2.0 FRACTURE MECHANICS ANALYSIS

Fracture mechanics analysis techniques as used in Apollo Program Working Paper 1325, "Fracture Mechanics Analysis of Apollo Block I Titanium Alloy Pressure Vessels (CSM)," are applied in formulating the testing policy. The paper presents the results of an analysis of Block I Apollo CSM titanium alloy pressure vessels. The proof pressure test is used as the base line for the evaluation of the pressure vessels with respect to maximum flaw size possible after proof testing. It shows that in some cases maximum operating pressure of the vessels could cause flaw growth if the maximum flaw which would allow a successful proof test existed in the tank. In all cases, however, the normal operating pressure is below the pressure which would cause flaw growth. Figure 1 will be referred to in the following general discussion.



K_{1C} - function of the tank material

Threshold - function of material and fluid, determined experimentally

D.L.P. - Design Limit Pressure - full flow value of the tank relief system or maximum design operating pressure (MDOP)

K_{1C} is the minimum value of the fracture toughness parameter for the material in question. This parameter describes the maximum flaw that a material can tolerate without rapid fracture when loaded to a prescribed stress level. The threshold curve is a stress intensity ratio at which value flaw growth will result and will continue to grow to failure. Below the threshold value, observable growth does not occur. This threshold curve or threshold stress intensity is a function of the fluid, material and temperature and is a measure of fluid compatibility under the specified operating conditions.

The rationale that results from the analysis is as follows. By applying a proof pressure of 1.33 DLP, the point σ_A on K_{1C} is established and a vertical line is then constructed to the abscissa. It should be noted that if the

pressure is maintained at σ_A, failure will result. This implies a short test time for proof testing. If failure does not occur, then it can be assumed that flaws will be of such a size as to be to the left of the established line. This forms the base line for all future testing of the pressure vessel.

The intersection of the line resulting from the proof test with the threshold line determines the point σ_B. This then establishes the maximum pressure permitted in any future test of the pressure vessel with a compatible fluid. Any test requiring a pressure above this value places the material in a flaw growth area with subsequent weakening of the pressure vessel and loss of confidence in vessel integrity.

3.0 PRESSURE VESSEL TESTING POLICY

The following policy for testing spacecraft pressure vessels was proposed by MSC with no objections from the LM/CSM contractor representatives.

1. Limit pressure proof testing of vessels to one test at 1.33 x Design Limit Pressure (DLP) at acceptance testing of the vessel.

2. Limit future tests to 1.0 x DLP except for functional testing of relief valves where a small Δp above DLP is required but is below the flaw growth point. MSC structures and mechanics representatives discussed a requirement for one test at 1.2 x DLP for systems verification in the spacecraft but there appears to be no rational need for such a test if replacement verifications are limited to 1.0 x DLP.

3. Limit subsystem verification, component replacement verification and new joint integrity to 1.0 x DLP.

4. Subassembly and component proof tests will not exceed 1.5 x DLP except for tanks which have been set at 1.33 x DLP.

5. Minimize test operations requiring cyclic pressurizing to DLP where DLP is very close to the flaw growth lines. This is of some concern when using Freon as the testing fluid.

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